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50 YEARS of Agricultural Research at the

USDA

NEWELL FIELD STATION

Newell, South Dakota

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Agricultural Research Service

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in cooperation with South Dakota Agricultural Experiment Station

CONTENTS

In observance of 50 years of agricultural research at the U.S.D.A. Newell Field Station, Newell, S. Dak., Field Day, held on July 20, 1957, this pamphlet reviews past accomplishments of the Station and projects future programs of vital research to serve agriculture of the Great Plains.

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FIFTY YEARS OF AGRICULTURAL RESEARCH

at the

USDA NEWELL FIELD STATION

Newell, South Dakota

H. E. Weakly, N. A. Dimick, J. R. Thomas, J. J. Bonnemann, A. Osenbrug,
L. F. Bush, J. W. McCarty, Armine R. Kuhlman, and B. A. Krantz

Farmers today are following management practices, planting improved-crop varieties, and using machinery, fertilizers, pesticides, feeds, and conservation techniques which were unheard of half a century ago. This Fiftieth Anniversary Pamphlet of the U.S.D.A. Newell Field Station reviews past accomplishments and looks forward to a future program of vital research to serve the agriculture of the Great Plains region.

Newell Field Station

1907

1957
(Note Chinese Elm hedge.)

History of the Station

H. E. Weakly

The Newell Field Station of the United States Department of Agriculture has been known by various names during its 50-year history -- an indication of the close cooperation between several Federal and South Dakota agencies. Nevertheless, a well-balanced program of research has always been maintained and a stable and profitable agriculture has been established in the region. Individual farmers have also been helped to know what crops to grow and how to grow them.

The Belle Fourche Reclamation Project was one of the earliest stations authorized by the Reclamation Act of 1902. In 1903 survey work on the project was begun and in 1905 construction was begun on a townsite named for F. H. Newell, who was then director and chief engineer of the U. S. Reclamation Service. In 1907 the Office of Dry-Land Agriculture Investigations, Bureau of Plant Industry, of the U. S. Department of Agriculture, under the direction of E. C. Chilcott, established the Belle Fourche Experiment Farm at Newell, S. Dak., with the Reclamation Service supplying $5,000 for fencing and other construction on the farm. In 1950 the station name was changed to the Newell Irrigation and Dryland Field Station. Then in January 1957, the name was shortened to the Newell Field Station.[1]

In 1907 when the work was started, information on dryland farming in the semiarid portion of the Plains was almost completely lacking and recommendations on how to grow crops on limited rainfall were based chiefly on experience from the humid area of the Plains and on untested theory. In 1912 the Belle Fourche Irrigation District began to furnish water to the station and irrigation-farming investigations were initiated to study the production and utilization of crops adapted to this area.

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1. The station contains 360 acres of land acquired as follows: The NE1/4, sec. 24, T. 9 N., R. 5 E.5 was set aside for the demonstration farm in 1906 by Executive Order. The SE1/4 of NW1/4, sec. 24, T. 9, R. 5, was withdrawn from entry by the U. S. Department of Interior and added to the farm in 1909. The S1/2 of SE1/4, sec. 13, T. 9, R. 5 was withdrawn from entry and added to the farm in 1911 to add some additional land for experimental purposes and to provide a site for a stock-water pond on Deadman Creek near the north boundary of the tract. The NE1/4 of NW1/4, sec. 24 and the SE1/4 or SW1/4, sec. 13 were withdrawn from entry in 1917 and added to the station.

Farm-shelterbelt studies were carried out under both dryland and irrigated conditions in cooperation with the Forest Service of USDA, which furnished much of the stock used for the plantings. Of the many tree species studied, the following have been quite successful under both dryland and irrigated conditions: Native red cedar, western yellow pine, honey locust, Russian olive, American elm, Chinese elm, caragana, tartarian honeysuckle, Persian lilac, and buckthorn.

Irrigated Forestry Project

Planted in 1913

After 15 years' growth

During the 50 years, a wide range of investigations have been undertaken. A brief summary of the major accomplishments of dryland research, irrigation farming studies, and livestock investigations will be discussed later in this publication. Many other investigations have been started and terminated during this period which can not be covered in detail. Among them were:

Alfalfa
- Fall irrigation
- Seed production
- Time-, method-, and rate-of-seeding
- Variety trials

Breeding drought-resistant crops
Effect of time of breaking prairie sod
Fall irrigation of various crops
Flax
- Date-and rate-of seeding
- Frequency of irrigation
- Variety trials

Forestry trials
Harvesting various irrigated crops with livestock
Potato variety trials
Production of feeder pigs
Small grain variety trials, both dryland and irrigated
Subsoiling dryland for crop production
Tillage with dynamite
Use of heavy clay soils as a building material

C. A. Jensen was the first superintendent and agronomist at the Newell Field Station. During his tenure from 1907 to 1909, construction was started and preliminary dryland investigations were carried out.

Beyer Aune became superintendent in 1909 and served in this capacity until his death in 1942. In addition to his duties as superintendent, he also had charge of the livestock and irrigation-farming investigations. The following is a fitting tribute to Beyer Aune's 33 years of service by Director I. B. Johnson of the South Dakota Experiment Station.

> "When Beyer Aune in 1909 assumed the duties as Superintendent of the Newell Field Station, it was in the pioneer stage of development. Mr. Aune was a graduate of the University of Minnesota, and during his student days was one of the University's illustrious football players.
>
> "Under his efficient management the Station developed from a raw prairie to one of the country's outstanding field stations. The agricultural research work conducted during Aune's management became a guiding light for many phases of agriculture in the Northern Great Plains.
>
> "Mr. Aune was not only an efficient station superintendent, but he took an active part in all community affairs. He helped to organize the first 4 H lamb feeding club in this country. He supervised the work of the local club until his fatal illness of 1942. He was also a director and later secretary of the Butte County Fair, taking responsible part in developing a general interest in livestock of better type and quality for the Plains.
>
> "At the time Mr. Aune became superintendent the station was changed from a development farm to a full-fledged experiment station, and its direction was changed from the Office of Dry-Land Agriculture to the Office of Western Irrigation Agriculture."

Carl A. Larson served as superintendent and soil scientist in charge of irrigation from 1942 to 1945. Dr. Larson is now superintendent of the Umatilla Field Station at Hermiston, Oregon.

A. Osenbrug, who was in charge of the dryland research from 1927 until his retirement in 1955, served as acting superintendent during the interim period 1945 to 1946.

Superintendents of the Newell Field Station

C. A. Jensen. 1907-09

Bever Aune. 1909-42

Carl A. Larson, 1942-45

Harry E. Weakly, 1946-56

Harry E. Weakly, who had been assistant agronomist at the North Platte Field Station, served as superintendent and agronomist in charge of irrigation research from 1946 to December 1956.

Niel A. Dimick, agricultural engineer, transferred to the station in June 1955 to conduct irrigation management research on the Angostura Project and at the station. He has served as acting superintendent since January 1957.

The station has had many men on its staff who have become outstanding in their field of endeavor. O. R. Mathews, agronomist at the station from 1909 to 1926, retired from the U. S. Department of Agriculture in 1955 to take a foreign assignment. He contributed 46 years of outstanding service in dryland agriculture. Other agronomists in irrigated and dryland crop research include: Reiner Bonde, Ross D. Davies, A. C. Dillman, A. D. Ellison, A. Hammerberg, E. M. Johnson, John H. Martin, George Ratcliffe, S. C. Salmon, and John Wentz. Bruce L. Baird was soil scientist from 1950 through 1954. Under his guidance fertility work was initiated off-station on the irrigated soils of the project. Sam H. Bober, who is now chairman of the Newell Field Station Advisory Committee, was the junior animal husbandman at the station from 1915 to 1918.

Staff of the Newell Field Station, January 1957.
Front row: Carl Orwick, Andrew Syverts, Dr. James R. Thomas, and Leo C. Walloth. Back row: Earl J. Kumpula, Alfred E. Barber, Marie R. Nissen, Niel A. Dimick, and Joseph J. Bonnemann.

Climate and Soils

J. R. Thomas and H. E. Weakly

Climate

Crop production in the dryland area is more dependent on the amount and distribution of the rainfall than on any other climatic factor. The annual average precipitation during the 49- year period (1908-1956) was 15.67 inches. The extreme range was from 28.21 inches in 1946 to 6.64 inches in 1911. The seasonal average (April through September) was 12.04 inches. The distribution of rainfall varies from year to year, but the general trend is for the maximum precipitation to occur in June. Destructive storms occur frequently in this area. High winds accompanying rain and hailstorms have seriously reduced yields.

Evaporation is an index of the demand for water by crops. The quantity of water evaporated in a day depends on the combined effects of humidity, temperature, and wind velocity. The average evaporation from April through September was 35.16 inches as measured in a Bureau of Plant Industry Type Pan[2] which is 6 feet in diameter and 24 inches deep.

Highest average wind velocities occur during March and April with velocities of 6.3 and 7.1 miles per hour, respectively. The annual average and seasonal average wind velocities are 5.6 and 5.4 miles per hour, respectively. Damage to crop production is generally caused by high-velocity winds over a short period of time. During these periods evaporation and transpiration may be so rapid that the plant appears to have been burned. Plants may also be damaged by the cutting action of wind-borne soil particles.

Temperatures at the Newell Field Station in the 49 years under consideration ranged from as high as 110° F. to as low as -38° F. The average mean temperature was 45° F. June, July, and August had average temperature of 65° F., 73° F., and 70° F., respectively. (A temperature of 32° F. is considered a killing frost.) The average frost-free period is 137 days.

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2. Brown, Paul L., and Hallsted, A. L. Comparison of Evaporation Data from Standard Weather Bureau and Plant Industry Type Evaporation Pans. Agron. Jour. 44:100-101. 1952.

Soil Characteristics

The soils on the Newell Field Station are comprised of Pierre clays and allied soils. The Pierre clays are residual soils developed from underlying Pierre shales. They are exceptionally heavy soils ranging in texture from a silty clay loam through a heavy clay. The Pierre clay soil is dark grayish brown in the upper layers, shading into the olive-gray color of the parent material at depths of 3.5 to 6 feet. The topography is gently rolling to hilly and broken. On the more level upland areas and in the bottomlands where drainage is imperfect, soil formation has been influenced by the accumulation of salts. The natural fertility of the Pierre clay soils is fairly good, even though the organic matter content is low.

Due to a high clay content, 34 to 54 percent, the Pierre clay soils become very sticky and plastic on wetting and are easily puddled. At low-moisture content these soils are hard and very coherent. Clods are produced if these soils are tilled in either a wet or dry condition.

Clods on fall plowed land -- a very dry Pierre clay soil.

Pierre clay soil very sticky and plastic when wet.

Construction of an experimental adobe-block house on the station in 1940

Working heavy clay soil

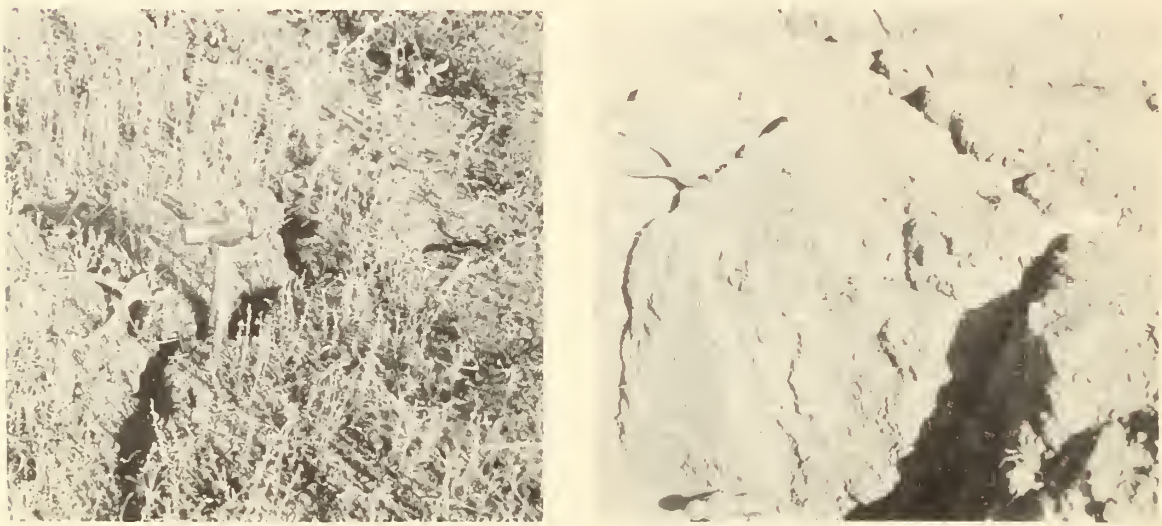
Drying the blocks

Laying walls which will
be stuccoed later

The finished house

Water permeability is very poor. In a study of the movement of water through an undisturbed core of Pierre clay soil, it was observed that after 29 days water had penetrated to a depth of 6 inches. Initially water entered the soil at a rate of 0.53 inch per hour, however, after the first hour the rate of entry was 0.05 inch per hour and continued to decrease to a constant value of 0.01 inch per hour at the twentieth day. This marked decrease in water penetration was due to the swelling of the soil and the resultant reduction in pore space.

Except for the pronounced contraction of the Pierre clay soils on drying, the movement of water through the soil would be extremely difficult. Contractions cause the soil to check freely and form cracks which may extend to depths of 24 inches or more. These cracks provide effective channels for water entry into the subsoil. Mathews (25)[3] observed that the Pierre clay soil was "irrigated through the cracks" and "irrigated from the bottom up." Consequently the subsoil expands and becomes relatively impermeable to water, resulting in the formation of a perched water table. This is a temporary condition that may persist from 3 to 5 days.



Cracks occur in Pierre clay
as soil becomes dry and divides into blocks.

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3. Figures in parentheses refer to List of Publications, p. 40).

Because of their cohesive characteristics, the Pierre clay soils are quite resistant to wind action when they are wet or moist. Frost action in conjunction with the drying effect of wind during the winter and early spring, breaks the soil body into a loose mass of granulated particles. The fine particles blow away as dust and the aggregates blow into dunelike sand.

Wind erosion of Pierre clay soil

Drifts around a thistle.

Dunelike formation.

Dryland Investigations

J. R. Thomas and A. Osenbrug

Dryland research at the Station has been directed toward the establishment of a system of permanent agriculture on semiarid lands. Since in regions of limited rainfall successful crop production is dependent upon the conservation and efficient use of precipitation, it was essential that information be obtained on crop adaptation and the value of various cropping sequences and tillage methods.

Crop Adaptation

The growing of drought-resistant crop varieties was early recognized as a means of meeting the problem of moisture deficiency. Plant breeding work with cereals was initiated in 1907 by the Office of Cereal Investigation and with forage crops in 1908 by the Alkali and Drought Resistant Plant Breeding Investigations in cooperation with the Office of Forage Crop Investigations, all of the U. S. Department of Agriculture. The early work with cereals consisted of varietal trials and rate-, date-, and depth-of-seeding experiments. Findings were published in the USDA series (12, 24, 32).

Variety tests in recent years have been conducted in cooperation with the South Dakota Agricultural Experiment Station. The results of the small-grain variety trials and the corn-performance tests are published each year by the station.

In the plant breeding work on forage crops, selections were made of plants having the following characteristics: Drought and winter-kill resistance, superior forage yield, and good seed production. The results of this investigation were published in the Bureau of Plant Industry Bulletin 196 (16).

The average yields of the different crops grown in the dryland rotations served as indices of their adaptability to this region (Table 1). Some grains in continuous cropping or alternate fallow rotations were planted in the plowed ground, whereas, small grains following corn were seeded in disked land.

Table 1. Yields of crops in dryland rotations at the U.S.D.A. Newell Field Station, 1909-1955.

Crop	Previous crop	Length of rotation	Period grown		Average annual yields
		Years	Date	Years	Bu. per acre
Winter rye	Wheat	2	1923-55	33	13.0
Do	Corn	2	1923-55	33	16.2
Winter wheat	Fallow	2	1909-55	47	19.8
Do	Wheat	1	1909-55	47	11.7
Do	Corn	2	1909-55	47	17.3
Spring wheat	Fallow	2	1909-55	47	21.2
Do	Wheat	1	1909-55	47	12.9
Do	Corn	2	1909-55	47	17.9
Oats	Fallow	2	1909-55	47	43.3
Do	Oats	1	1909-55	47	26.7
Do	Corn	3	1909-55	47	36.1
Barley	Fallow	2	1909-55	47	34.5
Do	Barley	1	1909-55	47	21.1
Do	Corn	3	1909-55	47	27.5
Flax	Grass		1909-55	47	6.5
Corn - grain	Fallow	2	1909-55	47	20.6
Do	Corn	1	1909-55	47	14.2
Do	Small grain	3	1909-55	47	15.6
Do	Do	3	1950-55	6	12.3
Sorghum grain	Do	3	1950-55	6	23.0
Potatoes	Do	4	1909-51	43	65.6
					Lb. per acre
Corn - stover	(2)		1909-55	47	1,675
Sorgo fodder	(2)		1909-55	47	4,031
Grass[1]	(2)		1909-55	47	1,196
Alfalfa	(2)		1909-55	47	1,732
Sweetclover	(2)		1924-55	32	1,737
Red clover	(2)		1909-23	15	721

1. Bromegrass, 1909-1936; mixture bromegrass and crested wheatgrass, 1937-1955.

2. Average of all plots on which crop shown in Column 1 was grown.

Two crop-yield factors of importance are total production and dependability of production. Sorgo, with an average acre yield of 4,031 pounds of fodder, was one of the most dependable crops, and surpassed all others in the yield of forage. It failed completely in only 2 years, although there were several other years when yields were low. Corn was nearly as consistent in the production of stover but was not reliable for grain.

The small grains are fairly well adapted to the regional climate. Cereal-crop failures were approximately 18 percent. Spring wheat failed in 7 years because of drought and in 1 year due to hail. Three of the failures occurred in consecutive years. Notwithstanding the high incidence of failure, spring and winter wheat were the most dependable cash crops.

The most productive and drought-resistant crops were those used for feeding livestock. Hay crop failures, which approximated 11 percent, were caused by difficulty in securing stands in dry years.

Spring wheat

On manured land

On cornland without manure

Rotation and Tillage

The effects of different methods of cropping and tillage on crop production were studied under dryland conditions. The work consisted of annual cropping where different crops were grown on the same land year after year by different tillage methods; 2-year rotations where small grains were alternated with fallow or corn; 3-year rotations with 2 years of small grains and 1 of row crop or fallow; 4-year rotations consisting of a grain crop, a cultivated crop, another grain crop, and a fallow or a green manure crop; and 5- and 6-year rotations involving the use of grass crops or legumes. The results of these investigations have been published in USDA Technical Bulletin 454 (12) and in the South Dakota Experiment Station Circular 85 (27). Some of the major findings were as follows:

1. The yields of all crops on the heavy gumbo soil were greater on fall-plowed than on spring-plowed land. The advantage in favor of fall plowing was more pronounced with small grains and sorgo than with corn.

The average yield of spring wheat for the 47-year period, 1909-1955, was 13.2 and 11.2 bushels per acre on fall- and spring-plowed land, respectively. Sorgo on fall plowing produced approximately 14 percent more fodder per acre than on spring plowing.

Forage sorghum,
a most reliable dryland crop.

2. Depth of plowing had very little influence upon crop production. Plowing 7- or 8-inches deep resulted in slightly larger yields of most crops than plowing 4-inches deep. Subsoiling to a depth of 16 inches had no apparent effect on crop production.

3. The yields of all small grains on disked corn land were greater than on fall- or spring-plowed land. Spring wheat following corn produced 14.3, 16.1, and 16.6 bushels per acre on spring-plowed, fall-plowed, and disked ground, respectively. Forty-two percent more winter wheat was grown on disked corn-stubble land than on fall-plowed continuous wheatland.

4. Small grain yields on summer fallow exceeded those on fall plowed and disked cornland. Winter wheat on clean fallow produced 19.8 bushels per acre, as compared with 17.3 and 11.7 bushels per acre on disked cornland and fall-plowed land. Winter wheat failures were 14.9, 17.6, and 22.3 percent on fallowed, corn stubble, and fall-plowed land, respectively. When winter wheat yields after fallow were divided in half to allow for the loss of a crop during the year of fallow, the yield after fallow was 1.8 bushels per acre less than from continuously cropped fall-plowed land, and 8.4 bushels per acre less than on disked cornland.

5. The average yields of spring wheat and oats, following the plowing under of different green-manure crops, were lower than after fallow. Sweetclover growing later into the season depleted the soil moisture reserves to a larger extent than the field peas or winter rye and had the greatest depressing effect on grain yields.

6. The average yield of corn grain on clean fallow for the 47-year period, 1909-1955, was 10.3 bushels an acre a year. The yield after fallow was 3.9 bushels an acre a year less than from continuous cropping and fall plowing. Corn failures on summer fallow were below 4 percent and less than any of the other tillage methods under trial.

7. Yields decreased during the 47 years of cropping. The use of new varieties failed to maintain the productive capacity of the soil. Average crop yields during the 1909-1932 period were higher than those obtained for the period 1933-1955. In the 1909-1932 period the average crop yields were: Spring wheat, 18.1 bushels; winter wheat, 17.4 bushels; and corn, 20.4 bushels an acre. During the next 23 years the average yields decreased to 15.6, 14.8, and 10.9 bushels an acre, respectively. The seasonal and annual precipitation averages from 1909 to 1932 were 0.79 inch and 0.94 inch greater, respectively, than from 1933 to 1955. As the variation in rainfall distribution and in annual or seasonal precipitation during these two periods was not great enough to account for the differences in yield, the decrease in yields was associated with a decline in soil productivity due to such factors as the loss of surface soil through wind action and to the reduction in soil organic matter.

Wind Erosion

The erosion of soil by wind has been a serious problem ever since the land was broken from sod. Although erosion control was not the main purpose of the experimental studies undertaken at the Newell Field Station, observations were made on the influence of various tillage and cultural practices in checking soil movement.

Fall plowing usually resulted in a coarse cloddy surface which was resistant to wind action when first plowed. Although freezing and thawing during the winter may reduce the clods to small granules, which are highly susceptible to wind erosion, generally the surface was still rough enough in the spring so that soil movement was less than on smooth surfaces.

Soil blowing on corn and sorghum ground can be greatly reduced by leaving most or all of the crop standing on the field when it is husked. When these crops are used for roughage or silage, the crop should be cut with a high stubble. Further protection can be given by cultivation late in the fall leaving a roughened surface.

Fallow land should be handled in such a way as to leave a protective cover throughout the year. This can be accomplished by plowing when soil moisture conditions are such that a high degree of cloddishness will result, or by using tillage implements that leave stubble on the surface.

Soil Moisture

Soil moisture investigations have been carried on continuously since 1908. These studies were designed to determine whether differences in yield brought about by different tillage practices were due to the quantity of moisture conserved or to some other factors. Three methods of cultivation with wheat and corn were examined: (1) Spring-plowed land, continuously cropped; (2) early fall-plowed land, continuously cropped; and (3) cropping after fallow.

The first soil moisture determinations were made to a depth of 6 feet. It became evident, however, that the character of the soil restricted water penetration and root development to the upper 3 feet; although in favorable years, small grains on fallowed land may utilize some water in the fourth foot.

The quantity of water available for crop use in the soil at seeding time is related to the length of water-storage period, to the depth of root feeding of the preceding crop, and to the presence or absence of stubble cover on the surface.

A comparison of the different tillage practices shows that water storage on continuously cropped fall- and spring-plowed land was nearly the same. In similar studies at other Great Plains experiment stations, it has been observed that land that goes through the winter in wheat stubble and is plowed in the spring contains more available water than land that is plowed in the fall and goes through the winter bare. The dissimilarity between these observations is due to the weed growth after harvest and to the physical character of the "gumbo" soil. Spring-plowed land was usually wet when plowed, and on drying, baked into hard clods, leaving the soil in an open porous condition.

Approximately 2 inches more water is available under alternate cropping than under continuous cropping. This additional 2 inches of stored water produced approximately 9 bushels of grain per acre more than obtained with continuous cropping. There are two types of years when the extra water provided by fallow was of no benefit: Years when precipitation during the crop year was high enough to permit wheat on land cropped each year to mature without drought injury, and years so dry that even the additional water provided by fallowing was insufficient to produce more than a light crop. During the 47 years of this study, the additional water provided by fallow gave yield increases 75 percent of the time.

Methods of predicting yields based upon measuring the "available" moisture in the soil or the depth to which the soil is wet at seeding time have been successful in many areas. Data on the use of moisture by spring wheat at the Newell Field Station indicate that predicted yields are more reliable if based upon the soil moisture available at seeding time and the expected seasonal precipitation (26).

In an alternate wheat-fallow system the relation of yield, seasonal precipitation, and stored soil moisture at seeding was described by the function:[4]

$$Y = 2.02\ P + 1.58\ M - 5.10$$

where Y bushels of grain per acre were produced by P inches of rainfall and M. inches of stored soil moisture. This relationship was highly significant (R - 0.71). Following the production of the first bushel of grain, each additional inch of stored soil moisture increased the yield by 1.6 bushels.

The value of conserving off-season precipitation and increasing the quantity of moisture stored in the soil at seeding time is readily shown by this equation. The mean seasonal precipitation during the 47-year

4. Unpublished data compiled by J. R. Thomas.

period was 8.6 inches. With this amount of precipitation, the expected yields per acre with 1 and 5 inches of stored moisture are 14 and 23 bushels, respectively.

Soil-moisture determinations after corn brought out two reasons why small grain after corn suffers less from drought than when it follows small grain. First, corn normally leaves some water available to small grain in the root zone, even though the corn may have suffered from drought. Corn will fire and cease to use moisture under conditions in which a small grain crop will live and continue to use water. Second, corn roots do not appear to penetrate to a depth as great as do those of wheat. This results in a supply of moisture available to small grain being left in the third foot of cornland.

Use of Fertilizers

Although soil moisture is still the most important limiting factor in crop production under dryland conditions at the Newell Station, increasing evidence indicates that production is also restricted by an insufficient supply of nitrogen.

An investigation of the effect of commercial fertilizers on the yield and protein content of spring wheat was initiated in 1950. To land continuously cropped to wheat, nitrogen and phosphorus fertilizers were applied annually, alone, and in combination.

Crop response to nitrogen fertilizer was dependent upon the available moisture supply. In the more favorable years the application of 30 pounds of nitrogen per acre increased the yield of grain 4 to 5 bushels.

The protein content of the grain was increased from 12 to 14 percent by the use of nitrogen fertilizer. The highest protein percentage was obtained in the driest years.

Application of phosphorus fertilizer had very little influence on the yield of grain, straw, or the grain-protein content. The phosphorus content of the grain was increased through the use of superphosphate fertilizer.

The use of fertilizers did not reduce yields even in the driest years. The nitrogen-phosphorus fertilizers tended to give the crops a better start in the spring. Plant maturity was often advanced by the use of phosphorus.

This study pointed out the need for more information on the relationship between moisture and soil fertility levels. To this end, a new

experiment is being conducted at the Newell Station to study the effects of soil moisture at planting time on the response of spring wheat to applications of nitrogen and phosphorus fertilizers.

An experiment was initiated in 1948 to study the influence of fertilizers on the hay production and protein content of crested wheatgrass under dryland conditions. Ammonium sulfate, treble superphosphate, and manure were applied annually in various rates and combinations until 1951.

The use of manure and nitrogen fertilizer increased hay production. In the years in which fertilizers were applied, 1948-1951, the average per acre increase in hay yield due to annual applications of 60 pounds of nitrogen and 8 tons of manure was 705 and 240 pounds, respectively.

In this limited rainfall area, only part of the applied fertilizer may be utilized in any one year. This study showed that under prevailing climatic conditions the effect on hay production of applying 60 pounds of nitrogen per acre for 3 years was apparent for three subsequent cropping seasons.

The value of the hay produced during the period 1948 to 1954 through the use of nitrogen fertilizer is indicated in Table 2.

Table 2. Increased Yields of Crested Wheatgrass Hay in Relation to Cost of Nitrogen Fertilizers, 1948-1954.

Total Nitrogen applied, 1948-51	Total Yield[1] 1948-1954	Total value of yield[2]	Fertilizer cost[3]	Return above check and fertilizer cost
Lb. per acre	Lb. per acre	Dollars	Dollars	Dollars
0	3,406	25.54	0	
85	4,828	36.21	11.90	-1.23
170	6,209	46.57	23.80	-2.77
255	7,986	60.00	35.70	-1.24

1. Based on 5-percent moisture content.

2. Hay valued at $15.00 a ton.

3. Nitrogen cost $0.14 a pound.

When no fertilizer was applied 3.406 pounds per acre of hay were obtained for a return of $25.54 an acre. The addition of 255 pounds of nitrogen per acre during 1948-51 produced a total of 7,986 pounds per acre of hay having a value of $60.00, but the returns above the check yield was not quite sufficient to pay for the cost of the fertilizer.

The use of fertilizers improved the quality of the hay. Its protein content and the total amount of protein produced per acre were increased through the use of manure and nitrogen fertilizer. During the years in which the fertilizer was applied, the 60-pound nitrogen application increased the protein percentage from 9.1 to 13.6.

The value of the crude protein produced during the period 1949 to 1954 is shown in Table 3.

Table 3. Relation of fertilizers and the crude protein contend and value in crested wheatgrass hay, 1949-54.[1]

Total fertilizer applied, 1949-51	Total protein produced	Value of protein[2]	Fertilizer cost[3]	Return above check and fertilizer cost
Per acre	Lb. per acre	Dollars	Dollars	Dollars
Check	239	28.68	0	-
24 tons manure	478	57.36	48.00	-19.32
24 tons manure & 60 lb. N	648	77.76	56.00	- 7.32
60 lb. N	376	45.12	8.40	8.04
120 lb. N	508	60.96	16.80	15.48
180 lb. N	727	87.24	25.20	33.36
120 lb. N & 180 lb. P_2O_5	534	64.08	33.00	2.40

1. Based on hay at 5 percent moisture.

2. Based on cost of soybean meal at $0.12 a pound.

3. Nitrogen cost at $0.14 a pound, phosphorus at $0.09 a pound, and manure at $2.00 a ton.

When no fertilizer was applied, 239 pounds of protein was obtained worth \$28.68 an acre The addition of 180 pounds of nitrogen during 1949-51, produced 727 pounds of protein having a value of \$87.24 and a net return of \$33.36 above the value of the protein in the check treatment and the fertilizer cost.

These results indicate that the increase in crude-protein content from nitrogen application on crested wheatgrass hay was very profitable, however, the hay-yield increase based on hay valued at \$15.00 a ton was not quite sufficient to pay for the cost of the nitrogen applied. Manure application resulted in a small, but non-profitable increase in crude protein yield of the hay. There was no appreciable response to phosphate application.

HARVESTING:

From
cradle to combine
in 50 years

By hand 1910

By horses 1930

By combine 1956

Equipment used in threshing, 1930

Irrigated Farming Investigations

H. E. Weakly, N. A. Dimick and J. J. Bonnemann

Irrigation water management is of primary importance to the farmer on the Belle Fourche Irrigation Project. Irrigation research began at the Newell Field Station in 1912 when the first delivery of water was made. The early program was concerned primarily with crop adaptation, cropping sequences, soil management, and crop utilization by livestock. More recently, emphasis has been given to studies involving the best combination of production factors such as irrigation water management, fertilization, crop spacing, crop varieties, and other cultural practices for maximum and economical returns to the farmer.

Crop Adaptation

Small grains in rotations serve well as companion crops in establishing stands of alfalfa and sweetclover. On the Pierre clay soils, barley is preferred over oats as a companion crop since better legume stands are usually obtained. Barley also produced as much feed per acre as oats and is more desirable for fattening lambs. Spring wheat is less dependable on irrigated land than either barley or oats.

Small grain yields in bushels per acre obtained in variety trials conducted on the station during the past 5 years ranged from an average of 41.4 to 65.3 for oats, 41.4 to 65.3 for barley, and 23.1 to 33.1 for spring wheat. Varieties that are currently recommended for this area include: Oats--Osage and Mo.-0-205 (feed oat); barley--Traill and Liberty (S. D. 1776); and spring wheat--Rushmore and Lee.

Alfalfa is well adapted to the area. It is a dependable producer of feed and is used as a cash crop. Alfalfa in a rotation benefits all other crops by improving the physical condition of the soil and by increasing its nitrogen content. In manured and phosphated rotations, alfalfa yields averaged 4.6 tons per acre on the station. Adapted wilt-resistant alfalfa varieties are Ranger and Vernal.

Sweetclover has performed well although it is often difficult to obtain stands. It makes excellent pasture. When used as a green-manure crop it is comparable with alfalfa for improving soil tilth and increasing soil-nutrient availability but an unidentified root disease has caused considerable damage in recent years and has practically eliminated the crop in this area.

Sugar beet production on the clay soil is difficult and sometimes hazardous. Obtaining stands and cultivating seedlings are difficult because of the crusting and cracking of the soil. Research and experience have shown that satisfactory yields of sugar beets can be produced if they are planted early (by April 15) in a well fertilized soil with frequent irrigations. In a heavily manured 3-year rotation, sugar beets averaged 18.8 tons per acre.

Until the advent of the newer short-season hybrids, corn yields were low and undependable. Now, with applications of from 80 to 100 pounds of nitrogen combined with good irrigation practices 80-bushel corn is a reality. Corn yields on the irrigated clay soils have ranged from 63.4 to 79.3 bushels per acre during a recent 4-year study. The varieties best adapted mature in 80 to 90 days. Some currently recommended hybrids are Sokota 220 and 250, DeKalb 56, and Funks G-11 or G-18.

In corn variety trials on coarser textured soils, average yields have ranged from 98.2 to 117.5 bushels per acre. Adapted varieties on these soils with a relative maturity of 85 to 95 days are Funks G-18, Sokota 270, Sokota 262, and DeKalb 56.

The value of sorghums, such as Norghum and Reliance has been demonstrated. Because of their high yields, these two varieties are recommended in years when a shortage of irrigation-water supply exists.

Red clover, flax, winter wheat, and potatoes were found to be poorly adapted to the clay soils on the station.

Apples, plums, and small fruits, such as gooseberries, currants, raspberries, and strawberries have been grown quite successfully although an occasional crop will be lost or much reduced by late frosts.

Most garden vegetables have been produced very successfully. Some of the newer early-type tomatoes do very well. Cabbages, peppers, eggplant, carrots, and onions also produce well and show favorable response to ample applications of phosphorus and nitrogen fertilizer and manure.

Sugar Beets

With Manure

Without Manure

Diseased After Alfalfa

Under irrigation excellent lawns are established and maintained. Lawn grasses respond very noticeably to nitrogen fertilizer.

Among the ornamentals such shrubs as Van Houtta spirea, Persian lilac, tartarian honeysuckle, ninebark, buckthorn, dogwood, Chinese lilac, mock orange, and many roses grow well. Cotoneaster and Chinese elm make excellent trimmed hedges.

Perennial flowering plants such as peonies, chrysanthemums, columbines delphiniums, iris, daylilies, tulips, and lilies of the valley are adapted to the soil and climatic conditions of this area. Shorter season annual flowering plants including larkspur, pansies, snapdragons, petunias, and marigolds also are grown successfully.

Irrigated Crop Rotations

Irrigated crop rotation studies were started in 1912 to study soil and crop management problems on the irrigated clay soils of the Belle Fourche project. The following is a summary of the major findings of the long-term rotation studies which were continued until 1950.

Rotations alone will not maintain crop yields or soil productivity. Good yield can be maintained on the clay soils only when a good legume rotation is combined with adequate manuring and fertilizing, particularly phosphate. One will not work without the other.

In manured rotations all crops consistently outyielded those in unmanured rotation, however, sugar beets showed the greatest response to manure application.

Alfalfa was found to be one of the most valuable crops on the irrigated clay soils of western South Dakota. When well fertilized, alfalfa produced excellent yields of high quality forage and in addition had a beneficial effect on the other crops in rotations and improved the workability of the clay soils. Contrary to other crops, alfalfa produced well over a considerable period of continuous cropping as long as the fertility was maintained.

Alfalfa in the rotation benefited sugar beet yields less than any other crop. In rotation with alfalfa, beets immediately following alfalfa yielded less than following small grain or potatoes. This was due to the greater prevalance of sugar beet seedling diseases and other problems of stand establishment when beets followed alfalfa.

Sweetclover was well adapted for use in 2- and 3-year rotations. It exerted a beneficial effect on the tilth of the clay soil and made a good pasture particularly for sheep.

The lack of phosphorus was one of the major factors responsible for low crop yields in some rotations. In the long-time rotations, consistently high yields were found only when extremely high manure applications (12 tons of manure per acre per year) were made. Soil analyses and other supplemental studies indicated that this was the only manure treatment high enough to maintain the phosphorus in the soil at the desired level. These and other studies indicate that an average application of 50 pounds of P_2O_5 per acre per year are required to obtain maximum crop production on the irrigated Pierre clay soils.

Long-time rotations are best. Four- and six-year rotations permit diversification of crops which dimishes the possible build-up of plant diseases and insect populations and provide the best opportunity for a stable irrigation agriculture.

Irrigated Pasture Rotations

An irrigated pasture rotation was initiated on the Newell Field Station in 1950 on the site of the old rotation plots. This 7-year ro-

tation included corn, small grain, small grain as a companion crop for alfalfa-brome seeding, alfalfa-brome hay, and 3 years of alfalfa-brome pasture. Each of the pastures was divided using yearling steers in one half and the station's registered Corriedale sheep flock in the other half.

Sheep are easily handled on a pasture rotation of this type. Approximately 50 ewes and 75 lambs have been successfully pastured on 10 acres of irrigated pasture. The area has produced 250 pounds of mutton per acre in a period of 106 days. There has been very little trouble with bloat or other losses.

The yearling steers have gained well with 20 steers being pastured in a 10-acre area. Bloat has been a problem on these pastures with one or more steers being lost each season. Currently, the beef-feeding studies are being changed from pasture to dry-lot feeding of green-cut alfalfa-brome mixture to reduce bloat losses and improve feed utilization efficiencies.

Four of the seven blocks in this rotation were surveyed topographically and the surface modified in 1956 to provide for improved irrigation practices. The other three blocks will be treated similarly when they are plowed.

Off-Station Fertility and Irrigation Studies

In 1950, fertility experiments were conducted on farmers' fields in the Belle Fourche project to obtain information on the kinds and rates of commercial fertilizer needed for increased production of sugar beets, small grains, alfalfa, and corn. Results of these studies have provided a broader base from which recommendations can be made of direct benefit to farmers in the area. Sites were selected to represent typical soil conditions and adequate moisture was provided in most instances to maintain continuous growth of the crop being studied.

Sugar beet yields were significantly increased by fertilization in four of the six experiments conducted in 1950 and 1951. Nitrogen and phosphate applications increased sugar beet yields by 1.9 to 8.0 tons. Nitrogen application decreased root-top ratios while the phosphate application increased the ratio slightly. Applications of commercial fertilizer are a must when growing sugar beets, and the required amounts will depend upon the soil type and fertility level of the field.

Barley yields on a lighter textured soil were raised from 26 to 39 bushels an acre by the use of 80 pounds of nitrogen per acre. Spring

wheat on Orman clay also responded to both nitrogen and phosphorus fertilizers. Application of 80 pounds of nitrogen an acre increased the yield from 19 to 29 bushels an acre. The addition of phosphorus (40 pounds P_2O_5 an acre) along with nitrogen produced 32 bushels per acre. Protein content was increased from 11.7 to 12.5 percent by the application of 80 pounds of nitrogen.

Studies with alfalfa indicated that increased production could generally be expected with the addition of phosphorus. The first addition of phosphorus gave the greatest increase in yield per pound of fertilizer. Yields were maintained most consistently and economically over a 5-year period with initial applications of 60 to 120 pounds of available P_2O_5 an acre. There was no appreciable difference between banded and broadcast applications of the phosphate.

Corn was found to be very responsive to nitrogen application. On fields where nitrogen was needed, 50 to 60 pounds of nitrogen an acre were usually sufficient but on some soils it was profitable to apply as much as 100 pounds per acre where proper irrigation practices were used. Corn usually did not respond to direct applications of phosphorus. These and other results indicate that it is more advisable to apply the phosphate fertilizer to other crops in the rotation, such as alfalfa or sugar beets, rather than to corn. With adequate fertility and good irrigation practices, a population of 18,000 to 20,000 plants per acre gave optimum yields of corn grain. Somewhat thicker stands were needed to reach optimum silage yields.

During 1955 irrigation water and fertility management research was conducted on three predominant soil-texture groups of the Angostura project, Farland sandy loam, Gap silt loam, and Orman clay. Corn yields were markedly increased by both irrigation and fertilizer treatment at all three locations and top yields of over 100 bushels an acre were obtained. The optimum rate of nitrogen application was between 60 and 120 pounds an acre. There was no response to phosphorus application. Three to five properly timed irrigations were needed for optimum yields. There was a marked yield reduction when irrigations were omitted during the tasseling and silking period.

During 1956 research work on the Angostura Irrigation project was expanded to include variety trials with corn sorghum, residual-fertilizer studies, water and fertility management on field beans, and field demonstrations on corn production.

By combining good fertilization and water management practices in field-scale trials, corn yields of 110 bushels an acre were obtained on an Orman clay soil. This required the use of 120 pounds of nitrogen fertilizer and five irrigations. In corn variety trials on an Anselmo sandy loam, the best seven hybrids averaged 140 bushels an acre.

Livestock Investigations

H. E. Weakly, L. F. Bush, and J. W. McCarty

The agricultural economy of western South Dakota is based largely upon the livestock industry. Hence, research with livestock has been one of the major lines of investigation at the Newell Station and has contributed much to the development of the irrigation project and the surrounding area. The livestock work at the station was conducted in cooperation with the former Bureau of Animal Industry, U.S.D.A., from 1912 to 1922 and since that time with the South Dakota Agricultural Experiment Station.

The early livestock work was closely tied in with the irrigation farming studies and was primarily concerned with livestock management and utilization of irrigated crops. The workers at the station pioneered in the use of sheep, hogs, and cattle in harvesting standing crops such as corn. They found that harvesting certain field crops by pasturing with livestock resulted in higher returns per acre than harvesting in the usual manner and also gave marked increase in subsequent crop yields. In these studies, lambs were found to be somewhat more efficient than hogs in the utilization of standing corn.

A feeder pig project was inaugurated in 1915 under the direction of Sam H. Bober, junior animal husbandman. This project created considerable local interest and led to the development of a thriving feeder pig production industry in the early twenties in this area of the State.

A small flock of Hampshire sheep was started on the station in 1920 and maintained until 1942 to be replaced by pure bred Corriedales from U.S.D.A. foundation stock from Beltsville. This Corriedale flock, which is still maintained at the station, has been instrumental in establishing the breed in this area. At present this flock is used in the irrigated pasture project to study the production of lamb and mutton under these conditions.

Fall pigs on irrigated pasture.

Newell Field Station Sheep.

Prize winning purebred
Corriedale ram 1946

Lamb feeding trials were started at the station in 1927 to answer questions regarding the use of suitable combinations of feeds and fattening rations, methods of handling the feeds and the lambs, and supplements in fattening rations. Farm grown feeds--corn, barley, oats, alfalfa, sorghum fodder, western wheatgrass, and Sudangrass--were fed in different combinations with or without protein supplements, minerals, and a succulent feed in an attempt to find efficient rations for fattening lambs. The following is a summary of the major findings:

Satisfactory results were obtained when corn, barley, or oats were fed with alfalfa hay with or without protein supplements. Sorghum fodder, western wheatgrass hay, and Sudangrass hay with or without protein supplements were found to be poor substitutes for alfalfa hay.

Pressed beet pulp, dried beet pulp, or beet tops added to grain and alfalfa hay resulted in satisfactory gains. Beet molasses was profitable in some combinations but reduced profits in others.

Wilted beet silage stock.

"Topping out" lambs as they became finished for market proved a profitable practice in 3 years of investigations.

In 4 years' work the allowance of 25 square feet or 80 square feet per lamb did not significantly affect the death loss or feed-lot performance of feeder lambs. Feeding three times a day showed no advantage over feeding two times a day.

The relative merits of corn versus barley and chopped hay versus long hay were studied in a 3-year experiment. In these trials lambs fed corn made greater average daily gains and utilized the feed more efficiently. Chopping hay reduced the feed required per pound of gain but the cost of chopping more than offset the returns from feed saved.

Three lamb-feeding trials suggested the need for the addition of cobalt to livestock rations in this area. The addition of cobalt to fattening rations increased the rate of gain and feed efficiency. The response was greatest when prairie hay was fed as the roughage.

The value of treating feeder lambs for internal parasites was demonstrated in 1953 when treated lambs gained an average of 0.05 pound per day more than the controls.

A limited amount of work suggests that protein supplements may be self-fed when salt is mixed with the protein to control feed consumption.

In one trial little difference was noted in the feeding value of second-cutting alfalfa hay grown on irrigated gumbo soil or irrigated sandy soil.

Bentonite used as an additive to fattening rations did not significantly affect the rate of gain and feed efficiency of the lambs.

Veterinarians study control of

internal parasites of sheep

The use of hormone implants has resulted in increased rate of gain and feed efficiency. The carcass quality of the treated lambs was lowered, however. Because feeding hormones to lambs has been favorable, more research is being planned.

Preliminary work indicates that a vitamin D supplement may increase the growth of lambs and this work is being continued.

Lambs may self-feed on ground

corn and chopped alfalfa

The value of alfalfa hay for supplementing native hay for wintering bred ewes was demonstrated in work started in 1945. In terms of ewe gain and lamb and wool production a daily allowance of 2.5 pounds of native hay and 1.0 pound of alfalfa hay was equivalent to feeding 3.5 pounds of alfalfa hay.

Feeding similar ration to ewe lambs for the first two winters did not prove satisfactory. However, when 1/3 to 2/3 pound of barley was fed with 1.0 pound of alfalfa hay and 2.0 pounds of wheatgrass hay for the first winter and followed the second winter by an all-hay ration, as above, a satisfactory cumulative 2-year performance was obtained.

Swine Breeding and Feeding

Early work with swine was limited to full feeding practices on alfalfa pasture and to the utilization of grain, tankage, half sugar mangels, and alfalfa hay by both spring and fall pigs.

In 1943 a project on swine breeding, feeding, and management was initiated in cooperation with the South Dakota Agricultural Experiment Station. A closed herd of Hampshires was established to study methods of maintaining a high-producing herd. This herd was maintained as an inbred line, with the exception of an outcross in 1946, through the 1953 season.

Feeding trials on pasture compared the use of either wheat or corn as the only grain in otherwise balanced rations. In two seasons' comparisons, pigs fed wheat gained more rapidly and efficiently than pigs fed corn as the grain in the ration. Since 1946 locally grown grain supplies have been insufficient to warrant maintenance of the feeding trials.

The breeding herd was maintained as a closed herd using 2 or 3 boars and 12 to 16 sows each season. By 1953 inbreeding had been raised to 40 percent in the pigs, an average increase of 4 percent for each gereration. During that same period selections for the breeding herd had been based on an index for total productivity. In spite of rather rigid selection, livability of pigs and individual growth rate decreased as the level of inbreeding was raised. This result is the usual one with a rise in inbreeding. By 1953 livability of pigs was so low that it was difficult to maintain the line at the station. Because of this difficulty the line was moved to the agricultural experiment station at Brookings. In spite of the fact that this line was not a high producer as such, the line was found to be valuable in a rotation crossing program begun in 1947 at Brookings.

Work at the Newell Station became a part of the cooperative research of the Regional Swine Breeding Laboratory in 1949.

When the Hampshire line was moved to Brookings in the fall of 1953, it seemed advisable to use the swine facilities at the station to demonstrate the productivity of a continuous crossbreeding program. For this purpose crossbreds representing the seventh generation of a systematic rotation cross were placed at the station. Included in the cross were inbreds of the Hampshire, Poland China, Duroc, and Landrace breeds. In the initial cross inbred Hampshire gilts from the Newell line were mated to inbred Poland China boars. Gilts from the cross were mated to inbred Duroc boars. Landrace boars were used on three-way-cross gilts in the succeeding generation. Breeds were re-introduced in the same order by use of boars of the appropriate lines. Performance for three seasons at the Station has continued to indicate that systematic rotational crossing is an efficient system for market hog production in terms of fertility, livability, growth rate, and carcass quality.

An outstanding inbred Hampshire gilt from Station herd 1945

Watershed Studies

Armine R. Kuhlman

Water supplies for livestock, small irrigation projects, and villages are becoming of increased importance throughout the country. Many problems are involved in providing supplies that are dependable and economical; little research has been carried out in the northern Great Plains on these problems. In 1956, the Agricultural Research Service, in cooperation with the South Dakota Agricultural Experiment Station, and with the help of the Soil Conservation Service, began to lay the ground work for a research investigation that would supply solutions for some of the problems The headquarters for the investigations are at the Newell Field Station.

The objective of the investigation is to find methods of predicting dependable yields of water for small water storage projects in the northern Great Plains where runoff is mainly from melting snow and spring rainfall. Watersheds for which this information is needed range in size from about 50 acres to perhaps 100 square miles. For watersheds of greater size information from the U. S. Geological Survey is used.

It is planned that the investigations will be carried out by measuring the inflow of water and sediment to ponds and reservoirs. Agreements will be entered into with the owners and operators of the land on which suitable impoundments have already been constructed. Ponds and reservoirs, convenient to the Newell Field Station, are being selected so that a range of watershed size, cover condition, and soils will be represented. The information collected, when properly interpreted, can be used to predict, for similar areas, the dependable yields of water and probably loss of storage capacity due to sediment accumulations.

A Look to the Future

B. A. Krantz

Great progress has been made in farming in the 50 years since the establishment of the Newell Field Station. The present day farmer is adopting practices and is using machinery, fertilizers, feeds, herbicides, pesticides, plant varieties, animal breeds, and soil conservation techniques that were unknown a half century ago.

As we look ahead we must be cognizant of other significant changes that have taken place during this 50-year period. The population of our country has doubled and is now increasing at the rate of about 2-1/2 millions a year. Mechanization has replaced horsepower, and the millions of acres formerly used to produce feed for the horses are now used in food production. Our geographical frontier has vanished. Thus there are no new lands for agricultural expansion and our only frontier in agriculture today is in technology and research on our present acres. To meet the food, feed, and fiber requirements of our growing population every acre of land and every acre-foot of water must be put to its best use. This means that we must learn how to manage our soil and water resources so as to conserve them while still increasing agricultural production.

Today, as we celebrate this Golden Anniversary we should look upon it not only as a milestone of past accomplishments, but also as a springboard for a revitalized future research program to better serve the agriculture of this region.

The future program at the Newell Station will be geared mainly to the solution of problems of the area; however, it will also be closely coordinated with other research in the area so that broad principles can be developed which will have a general application to the farmers and ranchers of the Plains region. As in the past, the research program of the Newell Station will continue in the development of better plants and

animals; improved soil, water, crop, and livestock management practices; improved disease, weed, and pest-control measures; and other factors which will tend to improve production and lower the unit cost.

During the next 50 years, however, there will be greater emphasis on the conservation, development, and efficient use of our soil and water resources. Water is definitely the major limiting factor in the agriculture of the Plains region. All research at the Newell Station is being planned with full awareness of this fact and geared to the conservation and effective use of water under both irrigated and dryland conditions. This will require fundamental investigations on means of increasing water intake, reducing evaporation, and developing plant and soil management practices which will use water more efficiently. With the recognition of the importance of livestock economy in this area there will be much emphasis on soil, water, and crop research for feed production on irrigated rangeland to integrate with farming.

Recent research on climatological and crop data of the Plains and the possible improvement of long-range weather forecasting appear to open new avenues of research for fitting farm management practices to climatic conditions and for developing more stable agricultural production in this vast area.

In developing new machines, chemicals, varieties, breeds, feeds, and conservation and management practices, research has often not gone far enough in carrying out the necessary experimentation at the farm-unit level to fit together various promising new techniques or practices. Pilot farm research is needed to effectively do this job and the Newell Station should play an important role in meeting this future need.

The formation of the Newell Station Advisory Council is a good indication of the farmers' awareness of the need for up-to-date information. In 1956 a poultry project and a rangeland fertilization project were started as a direct result of requests from the Newell Station Advisory Council. The close liaison between this farmer advisory group and the station research workers will greatly aid in directing research toward the solution of the current and future problems of this region.

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